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Innovation Modes and Productivity in the UK

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Executive summary

This paper is motivated by the aim to develop appropriate indicators capturing modes of innovation by UK enterprises, examine how such innovation practices vary across regions and industries and explore the extent to which they have an impact on productivity. There is an emphasis on identifying and examining the relevance of non-technological innovation that builds on and extends previous research in this important area. Traditionally, measures of innovation have rested on single indicators such as patenting or R&D, supplemented, by product and process and process innovation outputs. More recently innovations in management, organisational and marketing areas are being brought into the picture and the relevant information collected by innovation surveys.

Among indicators of innovation the distinctions between technological and non-technological innovations has often been loosely translated into either activities in manufacturing versus services, or into product and process innovations versus organisational and marketing innovations. While these simplifications of technological and non-technological innovation can be a practically useful, since data is readily available, they do not fully recognize that mixed modes of innovations are adopted by today's firms; firms whose environments are characterised by increased competition, internationalisation and shorter product life cycles.

This study is an analysis based on the UK Innovation Survey, which is, in turn, part of a wider OECD project that aims at identifying modes of innovation practices, with similarities, but also significant differences, across countries.

The methodology applies an explorative approach to uncovering modes and patterns of innovation. We identify a set of variables measuring innovation relevant activities and examine which of these variables 'hang together' to form summary indicators of joint activities for effective innovation. In the first part of the paper, based on analyses carried out on a common basis across several OECD countries, we report the following four modes: (i) in-house/IPR innovating, (ii) process modernising, (iii) wider innovating and (iv) marketing driven innovating. A later section reports results using data specifically for the UK, which has a more extensive set of variables and observations. This adds two further modes – "open" and "skills based" innovation.

The extent to which such practices are adopted by firms is likely to vary between regions and industries. To shed further light on this, we apply cluster techniques, to group enterprises according to their innovation practices and to identify relative specialisation patterns.

The third step in this study is to link the innovation modes to productivity levels. Theory and empirical evidence suggest a positive link between innovation activities and productivity. In this report the emphasis is on contrasting the differences in effects across innovation practices. While assessing productivity levels, wider conditioning factors including measures of human capital, competition conditions and enterprise structure are included. Taking account of these conditions, some of the mixed modes of innovation are positively and significantly associated with higher levels of productivity, at least over a similar time period, which supports the proposition that economic performance relates in a complex way to innovation systems. Further work in the project will seek to estimate innovation and productivity links over time, as new data becomes available.

This study is relevant to policy because it addresses, in a systematic way, aspects of innovation that have received less attention in the analytical literature so far, than have pure technological dimensions based on R&D and patents.

Content

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1. Introduction

There is considerable evidence that innovation plays an important role in shaping the growth and competitiveness of firms, industries and nations. Innovation is linked to increased welfare, the creation of new types of jobs and the destruction of old ones. At the firm level, innovation is linked to performance and competitiveness.

Analysis and modelling of the economics of innovation has traditionally concentrated on the definition and role of technological changes, usually measured by R&D or patents. But the importance of other dimensions of innovation, such as managerial or organisational change, investment in design or in skills, and the management of the innovation process itself, are increasingly acknowledged as equally important. This is reflected in the new *Oslo Manual*. While the latter does not distinguish between technological and non-technological innovations, it recognizes the importance of organisational and marketing changes next to innovations in products and processes. However, with the amount of data now available from innovation surveys, it is possible to explore a much richer set of combinations of activities and outcomes to start to model the systemic nature of modern innovation.

This study constructs complex or summary indicators of innovation practices based on factor analysis to find out which activities are jointly undertaken by firms in order to bring about innovation and examines how such practices may vary across regions and industries.

This report is structured in the following way. Section 2 introduces the theoretical context of the study. Section 3 explains the data and methodologies. While Section 4 discusses the results and Section 5 concludes.

2. Theoretical context

This section provides the theoretical context, highlighting the emphasis on technological activities in early innovation related research, followed by a discussion of emerging concepts of the role and importance of non-technological activities.

Traditionally, empirical and theoretical works on the determinants and effects of innovation were confined to technological innovation activities (e.g. Cohen, 1995, Smith 2005). This is because a large proportion of innovations, specifically in high technology manufacturing sectors, are based on technological activities, including activities carried out in R&D departments (e.g. Fagerberg, 2005). Literatures on innovation have focused on two Schumpeterian notions- the introduction of a new product and the introduction of a new production process (Schumpeter, 1934). A similar approach to capturing innovation is suggested in the 2nd revision of the Oslo Manual with an emphasis on the technological component of such innovations.

> *A technological product innovation is the implementation / commercialisation of a product with improved performance characteristics such as to deliver objectively new or improved services to the consumer. A technological process innovation is the implementation / adoption of new or significantly improved production or delivery methods. (OECD, 1996: 8)*

With the introduction of the 3rd revision of the Oslo Manual in 2005, the above definition – now referred to as narrow definition of innovation – has been extended to encompass organisational and marketing changes, and to include non-technological characteristics of product and process innovations.

> *An innovation is the implementation of a new or significantly improved product (good or service), or process, a new marketing method, or a new organisational method in business practices, workplace organisation or external relations. (OECD, 2005: 46)*

The need to cover properly innovation in the provision of services, which dominate OECD economies, has also been a major force behind these changes in concept. In tandem with, if not somewhat ahead of, the shift in emphasis in the Oslo Manuals,there have been changes in the Community Innovation Survey (CIS) questionnaires and in similar innovation surveys in other countries. In CIS2 the definition of technological product and process innovations as recorded in the 2nd revision of the Oslo Manual was adopted; since CIS3 the word 'technological' has been dropped from the various questionnaire items measuring product and process innovation.

The recent changes in data collection are mirrored in empirical studies of broader measures and/or modes of innovation. For example, a number of recent papers focus on the determinants and effects of marketing and organisational types of innovations (e.g., Acha and Salter, 2004) and innovation in services (e.g., Diellal and Gallouji, 2001, Tether and Miles, 2001).

In conjunction with such research a loose distinction is made between technological types of innovations and non-technological types of innovation. By and large, product and process innovations in manufacturing firms are considered technological, whereas organisational types of innovations, marketing innovations and/or innovations in services are considered as non-technology based (e.g., Battisti and Stoneman, 2007). However, product and process type of innovations are likely to have non-technological components, and organisational and marketing innovation are often helped by technological knowledge. Confining non-technological innovation to organisational and marketing innovation may be, in practice, a convenient simplification given the variations in coverage and variables collected in innovation surveys across countries; however, is likely to give an inaccurate or at best incomplete picture of the extent of complementarity these dimensions of innovation inputs and outputs.

In particular, there is great heterogeneity in innovation practices across services sectors. Some innovations in services are technological, such as the introduction of advanced communication technologies. A proportion of innovations, however, are likely to be involve mostly non-technological inputs such as business practices or organisational adaptations. Innovations in the hotel and catering industries, for example, are mostly considered to be non-technological (Djellal and Gallouj, 2001).

Reflecting on the outcomes of innovation, accumulated analytical results suggest that both technological and non-technological innovation activities are relevant for firm performance. Firms that engage in both product and process type innovations and, at the same time, introduce organisational changes outperform firms that do either one or the other (Geroski, Machin and van Reenen, 1993).

A number of studies have aimed at identifying different modes of innovation practices related to the distinction between non-technological and technological elements. In particular, Hollenstein (2002) examines different modes of innovation in the service sector based on the Swiss Innovation Survey. In his paper, Hollenstein uses factor and cluster analyses to group firms into five categories which include specific ratings of their technological vs. non-technological activities. He finds that firms which engage in all activities are more likely to engage in cooperation and have a higher innovation output. Jensen, Johnson, Lorenz and Lundvall (2007) cluster firms into different modes of knowledge. These are "Science, Technology and Innovation" mode – which may be seen as closer to technological types of activities – and "Doing, Using and Interacting" mode – which may be closer to non-technological types of innovation – using the 2001 Danish DISKO Survey. They, too, find evidence that firms which engage in both types of knowledge generation and acquisition outperform in terms of product innovation output. In a similar vein see Howells and Tether (2007) using Innobarometer data.

In the UK, Battisti and Stoneman (2007) use the UK innovation survey to identify different modes of innovation activities. They, too, use both factor and cluster techniques to explore the data. The modes of innovation they identify are: "wide innovative activities", including marketing, organisational, management and strategic innovations; and "traditional activities", including product, process and technological innovations. They link these two modes to firm performance and find that "wide innovative activities" and "traditional activities" are complements rather than substitutes and enterprises engaging in both exhibit higher levels of performance.

Although the above studies concern a distinction between technological and non-technological activities, there remains considerable overlap between modes or classification of activities identified. This project uses similar methods to Hollenstein (2002), Jensen *et. al* (2007), Battisti and Stoneman (2007) and Peeters, Swinnen and Tiri (2004) for the purpose of exploring different modes of innovation, and links these to indicators of productivity to gain insight about the relative economic importance of different modes or strategies of innovations.

To-date this project is perhaps the most comprehensive attempt to identify and estimate the impacts of innovation practices across OECD countries; comprehensive in terms of the number of countries involved in the project, the number of variables feeding into the analysis and the number of observations used in each country. The study includes a diverse range of economies in relation to geographical location and economic development and cultural contexts, including countries in North and South America, South-East Asia as well as a group of small and large European economies.

We do not *a priori* expect to find wholly common patterns across regions, sectors and countries instead we expect the variations and the similarities to further our knowledge of how respective national, regional and sectoral innovation systems function. The next section introduces the datasets, variables and methodology, followed by a discussion of the results and conclusion.

3. Data and methodology

This section discusses data and methodology. The internationally comparable analyses are based on those questionnaire items in the fourth harmonized CIS questionnaire on which information is collected across all (or most) countries participating in the OECD project. Thus, we chose – in the first instance – to work with a smaller set of variables than may have been possible in specific countries including the UK. This choice, with the aim to achieve the highest level of comparability across countries, will tend to limit the ability of the models reported here to "fit" the salient characteristics of the individual countries. A later section summarises the results of extending the analysis to use more of the UK innovation survey variables, to give a richer picture at the national, regional and sectoral levels in this country.

3.1 Data

Variables for the international project were selected from the items included in the harmonized survey questionnaire of the Fourth CIS. Here, we introduce those variables, including their definitions, and make some reference as to whether or not an activity is likely to lean towards non-technological engagements. Our analysis of modes of innovation incorporates measures of innovation outputs, e.g. a new product, together with innovation inputs, e.g. R&D activities or patent application. These measures are summarised to represent modes of innovation – an example would be new-to-market product innovations together with in-house R&D and protection via intellectual property rights, and the latter may be classed as an innovation practice with a high technological component. Alternatively, practices may centre on design issues and new marketing strategies and lean towards non-technological engagements. We thus depart from a simple input-output way of framing the innovation process towards a more systems based approach.

Broad headings under which we introduce the selected questionnaire items feeding into the factor analyses are: product innovation, process innovation, marketing and organisational innovation, own technology, diffused and embedded technology, design and other inputs. Table 3.1 summarises the set of variable on the basis of which modes of innovation practices are identified.

Table 3.1 Variables included in the explorative analysis of non-technological and technological activities

Variable description	Variable names
Product innovation	
Introduction of a new-to-firm product (that was not new to the market)	New-to-firm product innovation
Introduction of a new-to-market product	New-to-market product innovation
Process innovation	
Process innovation (methods of manufacturing; delivery or distribution methods)	Process innovation
Organisational and marketing innovation	
New knowledge management system	New knowledge management
Change to the organisation of work, incl. management structure	New organisational structure
Changes in the relationships to other firms, incl. partnerships	New relations with other organisations
Changes in design or packaging	New design or packaging
Changes sales or distribution methods	New distribution methods
Own technology	
Intramural R&D	In-house R&D
Enterprise applied for a patent	Patent
Diffused and embedded technology	
Extramural R&D	Extramural R&D
Expenditure on acquisition of machinery, equipment and software	Machinery

Expenditure on external knowledge acquisition	External knowledge
Design	
Registered industrial design	Design registration
Claim copyright	Copyright
Other inputs	
Expenditure on training	Training
Expenditure on market introduction of innovations	Marketing expenditures

The left column of Table 3.1 gives a description of the questionnaire items and the right column the names used to identify the respective variable in this study. As *innovation outputs*, the surveys include information on innovations in products and processes, which may be based on both technological and non-technological activities. Under the title 'wider innovation outputs' the surveys include changes to management techniques and organisational structures, marketing strategies and the appearance of products, generally seen as non-technological related activities.

On the side of *innovation inputs*, we consider activities including in-house R&D as a largely technology relevant inputs through own generation of technology, together with inputs of bought in and diffused technology such as the acquisition of machinery, equipment and software, and other external knowledge. Moreover, innovation inputs captured in the surveys may be linked specifically to design functions and marketing activities. Whether or not a firm registered a design or used copyrights is used as a proxy for design related activities, which are partly non-technological, but also an important component of new and applied technologies. A survey question covers expenditure on marketing new innovations, considered largely a non-technological input. Finally, we include training of employees in connection with innovations.

The following restriction are applied to *sample selection.* Observations feeding into the analysis are from innovation active enterprises – innovation active according to a Eurostat definition. This is done for two reasons. First, because we are interested in exploring different practices among innovation active firms and second, because not all information included in Table 3.1 is available for non-innovation active enterprises across most countries. An enterprise is considered to be innovation active if it had a product innovation or a process innovation or any innovation activities to develop product or processes that were abandoned or still ongoing during the reference period of the surveys.
The data covers all manufacturing and most private services. The reference period for the innovation surveys is 2002 to 2004. The next section describes the statistical methods used.

3.2 Methodology

As discussed in Sections 1 and 2, the aim of this study is to identify modes of innovation, to compare these across different regions and industries (and in the case of the wider OECD project across countries) and examine their relative effects on productivity. Therefore, our point of departure – rather than operationalising and testing conceptual hypotheses – is to use observations to arrive at a new conceptual understanding of modes of innovation.

To address the above aims, the methodology applied in this report is threefold. First, we use factor analyses to derive different modes or practices of innovation. Second, we examine what combination of innovation practices are applied by groups of innovation active firms using a clustering technique. Third, we analyse the relevance of innovation practices in firm level performance by examining associations with productivity using regression models.

We use explorative (as opposed to confirmatory) factor analyses. The technique is used to reduce a set of variables into different concepts (factors) which summarise combinations of innovation: inputs and outputs. In other words, we would like to discover which variables (listed in Table 3.1) form coherent subsets. The variables of a subset are correlated with one another and the strength of their correlation is summarised in factor loadings. Variables which score high in one factor are largely independent of other factors, but with some exceptions, where loadings on a variable are similar across more than one factor.

All variables feeding into the factor analyses and included in Table 3.1 are measured on a binary scale. If an enterprise engaged in a specific innovation related activity, for example reporting a new-to-market product during the reference period of the survey, then the variable new-to-market product innovation is coded one, otherwise zero. Although, the innovation surveys contain continuous data for some variables included in Table 3.1, such as the amount spent on R&D, we do not use this information for technical reasons.

Therefore, we use binary data factor analysis (see for example Battisti and Stoneman, 2007). This involves the computation of a tetrachoric correlation matrix, and factor analysing this matrix, under the assumption that the observed binary variables correspond to latent continuous variables.[1] We retain the number of factors which have eigenvalues greater than 1; any deviation from this rule, i.e. the inclusion of factors with eigenvalues smaller than 1, is discussed in the relevant results section. We present results based on unweighted data, using principal component analysis and varimax rotation to generate the factors, unless specified otherwise. We also computed results based on (i) weighted data and (ii) oblique rotations and found the results to be highly similar to those presented here. Finally, an advantage of the factor analysis is that it provides indicators in the form of a set of factor scores for each firm in the sample, which can then be used as explanatory variables in modelling productivity responses to innovation. Regression methods were used to compute the factor scores, which have a low correlation amongst themselves. (Fidell and Tabachnick, 2006).

The factors - modes of innovation - are interpreted using inductive reasoning, i.e. moving from the specific observation to the general concept. This interpretation of underlying modes of innovation activity increases our understanding of what innovation strategies are prevalent across geographical or industrial domains.

A further stage of descriptive analysis of patterns in innovation behaviour is to group enterprises according to their values of the factor scores, by using k-means clustering technique with a random allocation of the first observation. We present four cluster solutions.[2] This enable propensities to a variety of innovation strategies – represented by cluster membership- to be derived for regions and industry groups.

[1] Results derived through principal component analysis based on Pearson correlation coefficients as well as the computation of polychoric correlation coefficients based on binary and continuous variables led to highly similar findings (and factors).

[2] We found that the five and six cluster solutions were not stable enough to be considered, i.e. depending on the randomly chosen starting point in the cluster analyses the results of the cluster solutions differed.

Finally, we use the factor scores computed for each firm in the surveys directly as variables in regressions predicting firm level labour productivity. Labour productivity is computed as the turnover in 2004 over the number of employees in 2004. This of course shows the broadly contemporaneous relationship – productivity in 2004 is "explained" by innovation characteristics over a three year period from 2002 to 2004. Additionally to exploring the impact of different types of innovation modes via the factor scores, we control for the effects of the following variable:

- We include a measure designed to capture the effects of human capital on our measures of performance and change in performance. This indicator is based on the number of employees that hold a degree irrespectively of the subject.
- We also estimate the impact of belonging to a wider company group on performance.
- We include a variable measuring the openness of the firm to international markets.

In the regression models we include a control variable capturing enterprise size, as well as sector and dummies. We compute marginal effects- the absolute change in the dependent variable induced by a one unit change in the independent variables, at the means of the regressors or for discrete changes from zero to one in the case of binary variables. Finally, we test the linear hypotheses of equality of the coefficients with respect to the factor scores, in order to assess any significant differences in impact.

4. Results

Here we discuss 1/ the results of the factor analysis, providing interpretations as modes of innovation, followed by 2/ the cluster analysis which groups enterprises according to their adherence to the modes. We explore the distribution of such groups of enterprises identified by their innovation practices across UK regions and industries. Finally, we include the factor scores (different modes of innovation practices) as explanatory variables in a regression explaining labour productivity.

4.1 Results of the factor analysis

The evidence on patenting and R&D spending are often taken to indicate that the UK is not among the very top performing countries in terms of innovation; yet recent economic trends, including productivity growth, suggest that the UK has been performing above the international average. This discrepancy between technology oriented indicators of innovation and performance in the UK might imply that innovation is less important for performance than usually thought, but more likely it points to the need for a wider and deeper understanding of the innovation practices which lead to improved performance. The analysis in the study aims at providing a contribution to that understanding through intensive use of the UK innovation surveys and international comparisons.

The factor analysis presented here in Table 4.1 is based on tetrachoric correlation matrix based on unweighted data. Four factors with eigenvalues greater than 1 are extracted and their correlations to the variables feeding into the analysis is summarised in Table 4.1. The correlations are also referred to as factor loadings. Descriptive statistics of the relevant variables are provided in the Appendix.

Table 4.1 Factor analysis

Variables	Factor 1 *In-house / IPR innovating*	Factor 2 *Process modernising*	Factor 3 *Wider innovating*	Factor 4 *Market driven innovating*	niqueness
New-to-firm product innovation	-0.03	0.04	0.10	**0.72**	0.47
New-to-market product innovation	**0.36**	0.14	0.17	**0.50**	0.57
Process innovation	0.00	**0.40**	0.27	**-0.62**	0.39
Advanced management techniques	0.08	0.17	**0.80**	-0.11	0.32
New organisational structure	0.16	0.05	**0.83**	0.03	0.28
Marketing change	0.10	0.14	**0.79**	0.15	0.33
In-house R&D	**0.40**	**0.47**	0.14	**0.37**	0.46
Patent	**0.95**	0.09	0.05	0.03	0.09
Extramural R&D	0.27	**0.63**	0.14	0.27	0.44
Machinery	0.01	**0.81**	0.05	-0.19	0.31
External knowledge	0.18	**0.73**	0.09	0.09	0.43
Design registration	**0.95**	0.07	0.07	0.03	0.09
Copyright	**0.91**	0.08	0.14	0.04	0.14
Training	0.05	**0.71**	0.24	-0.07	0.43
Marketing expenditures	0.25	**0.48**	0.29	**0.40**	0.46
Proportion of variance explained by each factor	0.21	0.19	0.15	0.11	0.65

N=5,203; CIS4; four factors with eigenvalues greater than one. Tetrachoric correlations, unweighted data, rotation method variamax.

The first factor which emerges from the analysis of the UK CIS is interpreted as a mode of innovation practice which we call *in-house/IPR innovating*. This factor is based on high loadings of protection of innovations from imitation, including patenting, design registration and copyrights. The in-house component is also linked to a relatively high loading of own technology. In-house/IPR innovating loads up with new-to-market product innovations. Innovation practices based on strong intellectual property rights are not unique to UK firms, but in the wider OECD study, emerge in countries with advanced innovation systems, such as France, Canada and New Zealand. Strategies of appropriation appear less relevant in smaller, perhaps more open, economies such as Austria and Denmark; or emerging economies such as Brazil and South Korea.

Factor 2, relates to an innovation practice which we call *process modernising*, based on process innovation, in-house R&D, external R&D and knowledge, as well as other inputs including training and marketing expenditures. In other words this factor summarises own generation of technology, diffused technology together with other activities (training and marketing). Throughout the OECD study we found that the acquisition of machinery and training tend to hang together with process innovation, however, own generation or diffused R&D tended not to be of high importance in process modernising. In two cases, Norway and New Zealand, process modernising is found in conjunction with managerial and marketing changes.

Factor 3 represents a practice we refer to as *wider innovating.* This factor links managerial, organisational and marketing changes.[3] Thus, enterprises which

[3] While the UK does not collect information on wider innovation in terms of new or significantly changed relations with other firms or public institutions as suggested by the harmonized CIS questionnaire, the UK innovation surveys collect information on the following over and above the harmonized CIS questionnaire: (i) implementation of

innovate in term of improved managerial techniques tend to advance the structure of their organisations and marketing strategies at the same time. Wider innovation practices are relevant in most countries. In some examples, such as Austria, we find that design related activities load up with this factor. In other countries we identify two distinct factor, one relating to management and organisational changes, and a second factor relating to marketing strategies, e.g. France and South Korea, where these activities are not necessarily combined.

Finally, Factor 4 combines innovation outputs in products, both new-to-market and new-to-firm, with marketing expenditures, and notably excludes innovations in processes. We call this factor *market driven innovating*, involving the importance of presenting new and improved actively products to customers. Market intelligence and marketing spending also loads up with own and diffused technology. The negative loading of process innovation may be explained by and linked to the product life cycle an innovation passes through.[4] For example, at the start of the product cycle firms are likely to be concerned with and compete via the introduction of new and improved products, whereas in the later stages of the cycle the emphasis shifts towards process innovation with competition based on improved efficiencies in the production of existing goods.

An interesting finding is that in-house R&D loads up positively, and therefore is relevant to three modes of innovation practices –in-house/IPR, process modernising and product innovating. Marketing expenditures emerge as relevant across two factors: process modernising and product innovating.

Following the factor analysis we save the factor scores as variables representing the four modes, for each enterprise in our dataset which are later used as independent variables in regressions on productivity and in the next section are used to cluster enterprises by innovation practice. The factor scores are standardized normal variables i.e. have a mean value of zero and a standard deviation of one across all observations.

4.2 Results of the cluster analysis

Here, we present the outcome of the cluster analysis. Cluster analyses groups observations (enterprises) by similarity across variables (factor scores). We compute a four cluster solution based on k-means cluster allocation. Figure 4.1 is a spider diagram of the four clusters with their respective values across the four innovation practices identified in Section 4.1. Across the whole sample (all enterprises) the mean factor score is zero and, thus, negative values indicate a deviation below the mean, that is a below average tendency to adopt a specific mode of innovation, and positive values indicate an above average inclination. The numerical information contained in Figure 4.1 is available in the Appendix at Table A.2.

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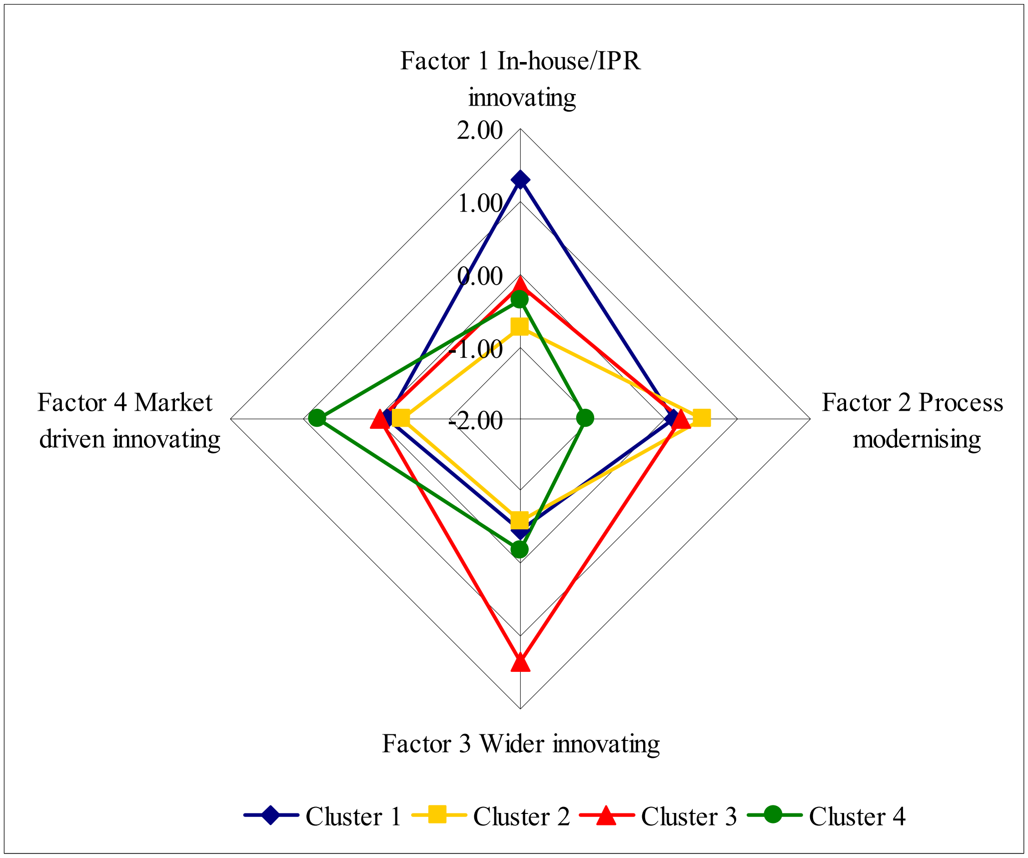
advanced management techniques, (ii) changes in the organisational structure, and (iii) changes in marketing concepts or strategies, which are used in this study

[4] We owe this point to Andy Cosh.

Figure 4.1 Cluster analysis



All four clusters obtained are of similar size, ranging from 1,094 to 1,517 enterprises. In Cluster 1 enterprises have in common that they engage in in-house/IPR innovating, and at the same time are below average in terms of wider innovating. In the following we refer to this group as *in-house IPR innovators*.

Cluster 2 contains enterprises that are above average in process modernising, and that are low with respect to in-house/IPR innovating and wider innovating. We refer to this cluster as *process modernisers.*

Cluster 3 is made up of enterprises that carry out process modernising and wider innovating, involving managerial, organisational and marketing innovations. We refer to this combination of innovating in processes and management/organisational aspects as *business process modernisers*.

Finally, Cluster 4 contains enterprises that engage in *marketing driven innovation* modes. Thus, with the exception of Cluster 3, enterprises are grouped predominantly by a single innovation practice which they have in common. While the factor analysis provides a definition of innovation practices, the cluster analysis groups firms according to these practices.

The following two tables, Tables 4.2 and 4.3, explore how firms in the four clusters are distributed across regions and industries. We compute an index of the regional distribution. Values above 100 indicate a relative concentration of firms a region/industry in that cluster and values below 100 indicate that enterprises are comparatively less likely to be part of that cluster in the region/industry.

Table 4.2 Distribution of clusters across UK regions

Region	Observations	Cluster 1 *In-house / IPR innovators*	Cluster 2 *Process modernisers*	Cluster 3 *Business modernisers*	Cluster 4 *Market driven innovators*
	Number	*Percent*	*Percent*	*Percent*	*Percent*
North East	264	97	117	104	76
North West	465	94	93	124	90
Yorkshire and Humberside	422	100	103	104	90
East Midlands	439	90	110	83	117
West Midlands	490	94	105	101	99
Eastern Region	467	112	95	83	113
London	511	89	89	113	114
South East	614	112	88	97	105
South West	413	106	96	91	109
Wales	340	120	102	91	84
Scotland	367	100	105	96	97
Northern Ireland	411	85	113	110	88
All enterprises	5,203	100	100	100	100

There are fewer enterprises that specialise in in-house/IPR innovation located in London and Northern Ireland compared with the remaining regions. Moreover, London and the South East exhibit fewer process modernisers. London based enterprises tend to be business modernisers, i.e. enterprises which at the same time introduce new processes jointly with upgrading management techniques and organisational strategies. Enterprises based in the capital also tend to bring about new products in conjunction with marketing activities.

Enterprises in the South East and Wales tend to be more likely to be in-house/IPR innovators. The North East and Northern Ireland exhibit the highest percentage of process modernisers, that is enterprises that emphasise process innovation based on bought-in equipment and training. Further, our data suggest that the Eastern Region and East Midlands have few business modernisers and the North East is specifically low on market driven innovators.

The regional story is likely to be linked to the industrial composition of the regions and to this we now turn. Table 4.3 gives an overview of the percentage of enterprises in each cluster by industry.

Table 4.3 Distribution of clusters across industries

Region	Observations	Cluster 1 *In-house / IPR innovators*	Cluster 2 *Process modernisers*	Cluster 3 *Business modernisers*	Cluster 4 *Market driven innovators*
	Number	*Percent*	*Percent*	*Percent*	*Percent*
Manufacturing of food, clothing, wood, paper	617	112	117	87	76
Manufacturing of fuels, chemicals, plastics,	885	133	88	85	94
Manufacturing of electrical and optical equipment	398	161	63	89	91
Manufacturing of transport equipment	198	158	83	87	67
Manufacturing not elsewhere classified	216	123	84	72	126
Wholesale, trade (incl. cars and bikes)	398	99	73	100	139
Retail and trade (excl cars and bikes)	273	50	118	86	152
Hotels and restaurants	172	55	134	98	111
Transport, storage and communication	378	66	125	107	98
Financial services	263	40	98	153	114
Real estates, renting and business services	1405	81	109	116	93
All enterprises	5,203	100	100	100	100

There are strong differences across the types of innovation practices used by enterprises depending on their industry. Services have fewer enterprises which are grouped into Cluster 1 – in-house/IPR innovators, in particular, financial services enterprises are less likely to belong to this type of innovator. Instead, service firms tend to be process modernisers, specifically in hotels and restaurants and transport, storage and communication.

Financial services are more likely to be business modernisers; i.e. processes are modernised in conjunction with improvements to organisational and management structures. Retail and trade firms are specifically engaged in market driven innovations.

High-tech manufacturing including electrical, optical and transport equipment and chemicals are businesses where an above average number of firms is clustered into the group that uses in-house/IPR innovation practices, i.e. protection of innovation from imitations through patents, design registrations and copyrights. Medium-low tech manufacturing, such as food, clothing and wood, contain a relative larger proportion of process modernisers. We now turn to the link between different innovation practices and productivity.

4.3 Results of the regression analysis – international model.

Table 4.4 gives the overview of the regression models relating productivity to innovation modes and other market and industry conditions. Descriptive and correlation tables are included in the Appendix: Tables A.3 and A.4. The dependent variable is the level of turnover per employee and the key independent variables are the factor scores of the four factors computed in Section 4.1 representing the four modes of innovation practices: (i) in-house/IPR innovating, (ii) process modernising, (iii) wider innovating and (iv) market driven innovating.

4.4 Regression results

Estimation methods OLS	Dependent variable: log of turnover per employee		
Independent variables	*Beta*	*S.E.*	
Factor 1: in-house/IPR innovating	0.06	0.02	***
Factor 2: process modernising	0.01	0.01	
Factor 3: wider innovating	0.02	0.01	†
Factor 4: market driven innovating	0.00	0.01	
Control variables			
Part of a company group	0.16	0.03	***
International competition	0.14	0.03	***
Human capital	0.05	0.00	***
Cooperation with the science and tech base	-0.01	0.04	
Information science and tech base	0.01	0.04	
Enterprise size	-0.02	0.01	
Manufacturing of food, clothing, wood and paper	base		
Manufacturing of fuels, chemicals, plastics,	-0.02	0.04	
Manufacturing of electrical and optical equipment	-0.03	0.05	*
Manufacturing of transport equipment	0.00	0.06	
Manufacturing not elsewhere classified	-0.02	0.06	†
Wholesale, trade (incl. cars and bikes)	0.20	0.06	***
Retail and trade (excl cars and bikes)	0.00	0.05	
Hotels and restaurants	-0.14	0.06	***
Transport, storage and communication	0.02	0.06	
Financial services	0.07	0.11	***
Real estates, renting and business services	-0.19	0.05	***
Number of observations	5,152		
F(48, 5104)	59.19		***
R-squared	0.19		

† p<0.10; * p<0.05; **p<0.01; ***p<0.001. Regression computed with constant. We report standardized coefficients and robust standard errors.

Table 4.4 suggests that Factor 1, *in-house/IPR innovating*, is positively and significantly related to productivity (beta=0.06; p<0.001). Further, there is some indication that *wider innovating*, i.e. managerial, organisational and marketing innovations are associated with higher productivity levels (beta=0.02; p<0.10). Testing the linear hypothesis of equality among coefficients, we find that the strength of the association between Factor 1 and productivity is statistically different, higher, compared with the remaining modes of innovation practices. In the case of New Zealand, we, too find a positive association between appropriation practices and increased productivity. Wider innovating is linked to increased productivity in the case of Norway and South Korea.

Perhaps somewhat surprising is that we do not find an association between *process modernising* and high levels of productivity in the case of the UK. However, similar innovation modes identified in the case of Austria, Brazil and Canada do show a significant association.

4.4 Results of the extended UK factor analysis and productivity regressions

This section presents results based on a wider set of variables and observations in the factor analysis, by using information collected in the UK innovation survey but not in other countries. With respect to observations, we include both innovative and non-innovative enterprises in the analysis. The dataset contains 11,091 enterprises.

With respect to variables, we are interested in exploring indicators which are incorporated in the UK surveys, but not in the harmonized version of the survey, to better reflect UK specific activities. These include new-to-market process innovations, changes to corporate strategy and expenditures on design. Moreover, we are interested in investigating the extent to which innovation modes may be characterised as ‘open’ practices through incorporating two cooperation variables – cooperation with the science base and cooperation with other firms. Additionally, we are interested in the extent to which different skill requirements feed into innovation practices and we include a variable measuring the proportion of scientists and engineers and other graduates.

Table 4.5 summarises the results of the factor analysis. We extract six factors with eigenvalues greater than one. The factors in-house/IPR innovating and wider innovating are the same factors reported in Table 4.1. Factor 2 links bought-in technology and training with new-to-firm innovations. Factor 4, which loads heavily on each type of product and process innovation,(new to firm and new to market or industry) we term *traditional innovation* One factor, Factor 5 links cooperation on innovation with own and diffused technology and new-to-market product innovations. We refer to this factor as *open modes of innovations,* referring to the high loading on the cooperation variables.

Factor 6 summarises the two skills variables. Exploring the two skills variables in greater depth, we find that scientists and engineers load up higher with in-house/IPR strategies, innovation outputs and open modes of innovation compared with other graduates. Other graduates have a higher correlation with wider innovation practices.

Table 4.5 Factor analysis based on the extended set of variables and observations

Variable	Factor1 *In-house / IPR innovating*	Factor2 *Bought-in technology*	Factor3 *Wider innovating*	Factor4 *Traditional Innovation*	Factor 5 *Open modes of innovating*	Factor 6 *Skill based innovating*	Uniqueness
New-to-firm product innovation	0.27	**0.30**	0.18	**0.48**	0.30	0.16	0.46
New-to-market product innovation	**0.40**	0.20	0.14	**0.57**	**0.37**	0.14	0.30
New-to-firm process innovation	0.13	**0.26**	0.21	**0.86**	0.18	0.09	0.10
New-to-market process innovation	0.17	0.15	0.16	**0.89**	0.17	0.04	0.10
Corporate strategy	0.13	0.11	**0.83**	0.18	0.16	0.13	0.20
Advanced management techniques	0.13	0.20	**0.77**	0.13	0.13	0.07	0.32
New organisational structure	0.20	0.12	**0.82**	0.14	0.15	0.16	0.20
Marketing change	0.23	0.24	**0.73**	0.21	0.17	0.08	0.28
In-house R&D	**0.42**	**0.49**	0.16	0.29	**0.34**	0.20	0.32
Patent	**0.93**	0.11	0.09	0.10	0.15	0.13	0.06
Extramural R&D	0.28	**0.54**	0.17	0.10	**0.46**	0.11	0.36
Machinery	0.14	**0.77**	0.14	**0.32**	0.06	0.07	0.26
External knowledge	0.20	**0.72**	0.16	0.05	0.29	0.04	0.33
Expenditure on design	0.41	**0.59**	0.13	0.24	0.21	0.13	0.34
Design registration	**0.95**	0.14	0.11	0.09	0.04	0.09	0.06
Complexity of design	**0.84**	0.21	0.18	0.25	0.14	0.17	0.11
Copyright	**0.90**	0.14	0.16	0.10	0.12	0.11	0.10
Training	0.17	**0.75**	0.24	0.26	0.11	0.09	0.26
Marketing	0.32	**0.57**	0.27	0.26	0.25	0.11	0.36
Scientists and engineers	**0.30**	0.08	0.09	**0.16**	**0.17**	**0.81**	0.19
Other graduates	0.16	**0.11**	**0.20**	0.03	0.07	**0.87**	0.17
Cooperation science base	0.18	0.16	0.16	0.17	**0.89**	0.12	0.09
Cooperation other firms	0.12	0.16	0.19	0.23	**0.88**	0.07	0.08
Proportion of variance explained	0.19	0.15	0.13	0.12	0.11	0.07	0.78

We repeat the estimation of the relationship between productivity, as measured by output per employee in 2004, and the extended set of six UK specific innovation modes, and the results are summarised in Table 4.6. As opposed to the results using the more restricted but internationally comparable factors, shown in Table 4.4, the dataset analysed here contains both non-innovative as well as innovative active enterprises and this explains, to some extent, the overall higher levels of significance.

Table 4.6 Regression results based on the extended set of variables and observations

Dependent variables	Labour productivity		
Independent variables	*Beta*	*S.E.*	
In-house/IPR innovating	0.07	0.02	***
Bought-in technology	0.03	0.02	***
Wider innovating	0.04	0.03	***
Innovation outputs	0.02	0.03	**
Open modes of innovating	0.01	0.03	
Skills based innovating	0.12	0.02	***
Control variables			
Group belonging	0.14	0.02	***
Foreign market	0.13	0.02	***
Enterprise size	-0.10	0.01	***
Industry dummies	Yes		
Number of observations	11,091		
F(47, 1,1043)	75.25		
R-squared	0.25		

† p<0.10; * p<0.05; **p<0.01; p<0.001. Regression computed with constant. We report beta coefficients/marginal effects and robust standard errors. Industry dummies are included in the estimates but the coefficients are omitted.

Here, more of the innovation modes are found to be positively and significantly associated with levels of productivity. In common with the internationally similar model, in-house/IPR innovating and wider innovating are significant. In this regression, however, traditional innovation (product and process) and, especially, skills based innovating are also significant.

5. Discussion and conclusions

This report argues why mixed mode measures of innovation practices are needed and attempts to identify such indicators based on the UK Community Innovation Survey and in comparison with a representative group of other countries. Using an internationally common set of survey variables, we find four distinct modes of innovation practices: (i) in-house/IPR innovating, (ii) process modernising, (iii) wider innovating and (iv) market driven innovating.

The study continues by grouping enterprises according to the extent to which they engage in combinations of these modes of innovation practices. We identify a group of enterprises concerned largely with an in-house/IPR mode (appropriation strategies), and a further group which brings about innovations largely through process modernising. The third cluster of enterprises engages in two distinct innovation practices – wider innovating and process modernising – and we call this group business modernisers. The fourth cluster contains enterprises pursuing practices of market driven innovating activities, i.e. practices by where firms push their new products through specialising in market activities.

Some interesting regional and sectoral differences emerge from the analysis. For example, enterprises in London are less likely to belong to the group of enterprises that engage in modes of in-house/IPR innovations, but instead are more likely to be business modernisers, a finding likely to be dominated by services enterprises located in London. In contrast to London, the South East and the Eastern Regions are dominated by enterprises which we engage in in-house/IPR innovating.

The regional patterns are linked to and supported by the industry comparison. Services on the whole are less concerned with in-house/IPR modes, and more concerned with process modernising and business modernising. Business modernising is specifically relevant in financial and communication services, of which in turn there is an agglomeration in London. High-tech manufacturing, including chemicals and electrical and optical equipment, are concerned with traditionally closed modes of innovation, i.e. IPR based practices.

Linking the modes of innovation practice with contemporaneous measures of productivity, we find a relative emphasis on in-house/IPR practices in the UK compared with other economies.

However, when using a more extended set of variables and observations, several types of innovation practices, including, wider innovation and skills based modes are significantly associated with higher levels of productivity, which highlights the complexity of innovation and the range of roles it performs in the economy. In terms of measuring innovation, these UK specific results confirm the importance of capturing non-technological investments and assets, which can constitute vital components of effective innovation strategies, both independently and acting as complements to technology

Next Steps

The analysis can be extended to take into account more dimensions of the innovation system that are covered in the survey data, including knowledge networks and linkages and the role of markets and users. Newly available data from a further round of the innovation survey and from other business surveys will enable more of the dynamic aspects – the longer term nature of much innovation and the consequent lags in the response of economic performance – to be incorporated in the estimates of impact. .

References

Acha, V (2006) Demand and Design Choices in an Open Innovation System Presented at the CIS user group, London, 17 November 2006.

Acha, V. and Salter, A. (2004) *Oslo manual revision 3 workshop for a chapter on the 'Economics of Innovation',* workshop report for the Department of Trade and Industry, November 2004.

Battisti, G. and Stoneman, P. (2007) *How innovative are UK firms? Evidence from the CIS4 on the synergistic effects of innovations,* Report for the Department of Trade and Industry 2007.

Cohen, W. (1995) 'Empirical studies of innovation activity' in P. Stoneman (ed.) *Handbook of the Economics of innovation and Technological Change,* Oxford, Blackwell, pp. 182-264.

Cox, H. and Frenz, M. (2002) 'Innovation and performance in Biritsh-based manufacturing industries: shaping the policy agenda' *The Business Economist,* 33: 24-33.

Diellal, F. and Gallouji, F. (2001) 'Innovation surveys for service industries: a review, in B. Thuriaux, E. Arnold and C. Couchot (eds.) *Innovation and Enterprise Creation: Statistics and Indicators,* Luxembourg, European Commission.

Fagerberg, J. (2005) 'Innovation: a guide to the literature', in J. Fagerberg, D. Mowery and R.R. Nelson (eds.) *The Oxford Handbook of Innovation,* Oxford: Oxford University Press, pp. 1-26.

Fidell, L.S. and Tabachnick, B.G. (2006) *Using Multivariate Statistics,*5th edition, Allyn & Bacon.

Geroski, P.A., Machin, S. and van Reenen, J. (1993) 'The profitability of innovating firms' *Rand Journal of Economics,* 24: 198-211.

Hollenstein, H. (2003) 'Innovation modes in the Swiss service sector: a cluster analysis based on firm-level data', *Research Policy,* 32: 845-863.

Howells, J. and Tether, B. (2007), Changing Understanding of Innovation in Services (Draft report for DTI)

Jensen, M.B., Johnson, B., Lorenz, E. and Lundvall, B.-A. (2007) 'Forms of knowledge and modes of innovation', *Research Policy,* in press.

Laursen, K., Salter, A. (2005) The paradox of openness: appropriability and the use of external sources of knowledge for innovation, paper presented at the Academy of Management Conference, Hawaii, August 2005.

OECD (1996) *Oslo Manual: The Measurement of Scientific and Technological Activities. Proposed Guidelines for Collecting and Interpreting Technological Innovation Data,* 2nd edition, Paris: OECD.

OECD (2007) *Science, Technology and Industry Scoreboard. Briefing note on the UK*, Paris: OECD.

OECD and Eurostat (2005) *Oslo Manual: The Measurement of Scientific and Technological Activities. Guidelines for Collecting and Interpreting Innovation Data,* 3rd edition, Paris: OECD and Eurostat publication.

Peeters, L, Swinnen, G. and Tiri, M (2004) *Patterns of innovation in the Flemish business sector: a multivariate analysis of CIS-3 firm-level data,* Report for the IWT-Studies: Brussels.

Smith, K. (2005) 'Measuring innovation', in J. Fagerberg, D. Mowery and R.R. Nelson (eds.) *The Oxford Handbook of Innovation,* Oxford: Oxford University Press, pp. 148-177.

Schumpeter, A. (1934) *The Theory of Economic Development: An Inquiry into Profits, Capital, Credit, Interest and the Business Cycle,* New Brunswick, N.J. London, Transaction Books.

Tether, B. and Miles, I. (2001) 'Surveying innovation in services: measurement and policy interpretation issues, in B. Thuriaux, E. Arnold and C. Couchot (eds.) *Innovation and Enterprise Creation: Statistics and Indicators,* Luxembourg, European Commission.

Appendix

Table A.1 Descriptive statistics of the variables feeding into the factor analysis

Variable	Mean	S.D.	Min	Max
New-to-firm product innovation	0.65	0.48	0.00	1.00
New-to-market product innovation	0.44	0.50	0.00	1.00
Process innovation	0.55	0.50	0.00	1.00
Advanced management techniques	0.30	0.46	0.00	1.00
New organisational structure	0.39	0.49	0.00	1.00
Marketing change	0.43	0.50	0.00	1.00
In-house R&D	0.62	0.48	0.00	1.00
Patent	0.38	0.49	0.00	1.00
Extramural R&D	0.26	0.44	0.00	1.00
Machinery	0.73	0.45	0.00	1.00
External knowledge	0.27	0.44	0.00	1.00
Design registration	0.38	0.49	0.00	1.00
Copyright	0.43	0.49	0.00	1.00
Training	0.67	0.47	0.00	1.00
Marketing expenditures	0.51	0.50	0.00	1.00

N=5,203.

Table A.2 Cluster analysis and data feeding into Figure 4.1

Cluster number	Number of observations	Factor 1 *In-house / IPR innovating*	Factor 2 *Process modernising*	Factor 3 *Wider innovating*	Factor 4 *Product innovating*
	Count	*Mean factor score*	*Mean factor score*	*Mean factor score*	*Mean factor score*
Cluster 1	1,327	1.29	0.11	-0.45	-0.16
Cluster 2	1,517	-0.74	0.52	-0.60	-0.37
Cluster 3	1,265	-0.15	0.21	1.35	-0.07
Cluster 4	1,094	-0.35	-1.09	-0.18	0.78

Table A.3 Descriptive statistics of the variables feeding into the regression

Variable	N	Mean	S.D.	Min	Max
Log turnover per employee	5,203	4.33	1.06	-3.93	12.68
Factor 1: in-house/IPR innovating	5,203	0.00	1.00	-1.37	1.89
Factor 2: process modernising	5,203	0.00	1.00	-2.86	2.42
Factor 3: wider innovating	5,203	0.00	1.00	-1.71	2.36
Factor 4: market driven innovating	5,203	0.00	1.00	-2.69	2.57
Part of a company group	5,186	0.48	0.50	0.00	1.00
International competition	5,163	0.54	0.50	0.00	1.00
Human capital	5,203	19.01	26.30	0.00	100.00
Cooperation with the science and tech base	5,203	0.15	0.36	0.00	1.00
Information science and tech base	5,203	0.76	0.42	0.00	1.00
Enterprise size	5,203	4.50	1.53	2.30	11.08

Industry dummies are excluded.

Table A.4. Correlations between variables feeding into the regression

	Variables	1	2	3	4	5
1	Log turnover per employee	1.00				
2	Factor 1: in-house/IPR innovating	0.14	1.00			
3	Factor 2: process modernising	-0.01	-0.08	1.00		
4	Factor 3: wider innovating	0.04	-0.05	-0.08	1.00	
5	Factor 4: market driven innovating	0.03	-0.07	-0.01	0.00	1.00
6	Part of a company group	0.23	0.18	-0.01	0.13	0.02
7	International competition	0.20	0.28	0.02	0.04	0.10
8	Human capital	0.02	0.13	0.05	0.12	0.03
9	Cooperation with the science and tech base	0.02	0.13	0.19	0.15	0.08
10	Information science and tech base	0.05	0.21	0.16	0.14	0.05
11	Enterprise size	0.09	0.18	0.03	0.19	-0.05

	Variables	6	7	8	9	10
6	Part of a company group	1.00				
7	International competition	0.18	1.00			
8	Human capital	0.06	0.13	1.00		
9	Cooperation with the science and tech base	0.08	0.16	0.16	1.00	
10	Information science and tech base	0.07	0.14	0.12	0.20	1.00
11	Enterprise size	0.39	0.11	-0.04	0.08	0.07

Industry dummies are excluded.

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